Transportation Energy Evolution Modeling (TEEM) Program

Zhenhong Lin
Email: linz@ornl.gov
Phone: (865)946-1308

Oak Ridge National Laboratory
National Transportation Research Center

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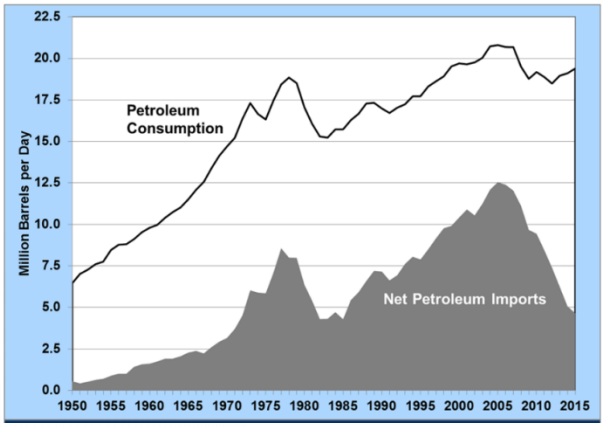
Overview

- Timeline
  - 10/2015-9/2018;
  - 80% completed
- Budget
  - $1.15m/year, planned
- Barriers Addressed
  - providing analytical capabilities in support of the other Tech Teams and the Partnership
  - continually maintaining up-to-date, validated vehicle component models, and developing appropriate test procedures as new technologies emerge
- Partners/Collaborators
  - ORNL team: Fei Xie, Shawn Ou, Stacy Davis, Zhiming Gao
  - Industry: Aramco, Denso, Energetics, SRA
  - Academia: UT Austin, U. of Tennessee, UC Davis, Iowa State U., U. of Florida, U. of Maryland, Georgia Tech, Clemson U.
  - Gov/Lab: DOE, ANL, NREL
  - International: Tsinghua University, CATARC, IIASA, KAPSARC

Transportation energy transition --why it matters?

- DOE VTO mission
  - "supports research, development (R&D), and deployment of efficient and sustainable transportation technologies" to … " increase America's energy security, economic vitality, and quality of life" (https://www.energy.gov/eere/vehicles/about-us)
- DOE & industry made technologies better
  - advanced batteries and electric drive systems
  - lightweight materials
  - advanced combustion engines
  - alternative fuels
  - energy efficient mobility systems



US Petroleum Consumption and Imports, DOE Fact of the Week #935

- To translate better technologies into societal impacts, market acceptance is key but complicated
  - Technology impact is achieved though consumer adoption
  - Consumers see technologies differently than engineers/scientists/economists
  - Suppliers seek more profits and less risks

TEEM goal—to develop/apply tools to analyze transportation energy transition

- The Energy Transition problem
  - How to efficiently and effectively transition and transform the current petroleum-based transportation energy system into a socially more desirable one
- A market dynamics modeling platform
  - Continuation and expansion of the MA3T model
  - Collaboration and integration with VTO models and other tools
  - Objectives: all highway vehicles, DOE and U.S. relevancy, comprehensiveness, user-friendliness, credibility, collaboration
- Outcomes: tools, publications, communications

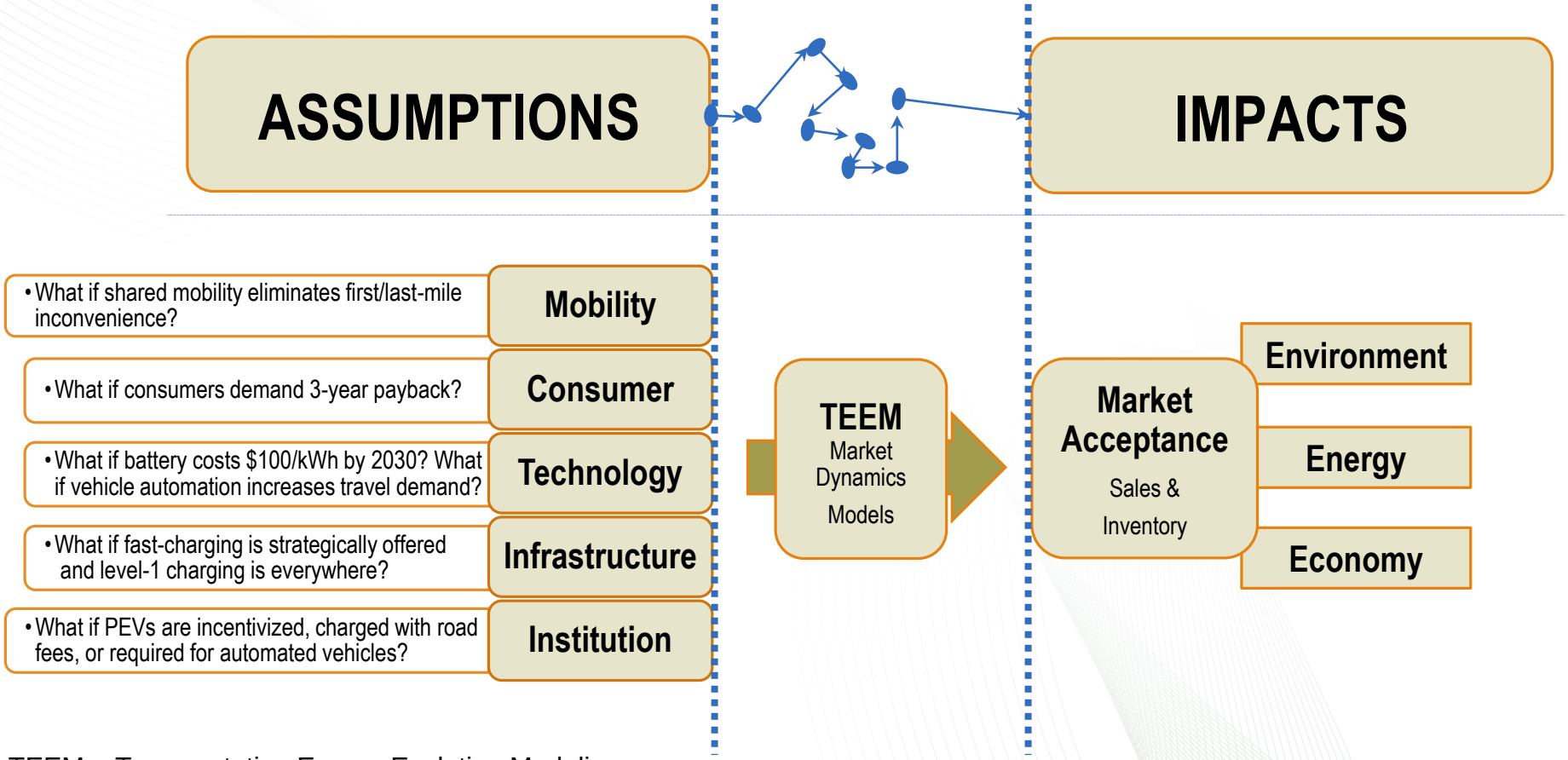
Note: some acronyms explained in backup slides

On track to meet all milestones

Milestone Description	Month/Year	Status
Project briefing and update to HQ on OSMM update and consumer segmentation in MA3T	12/31/2017	Complete
Project briefing to HQ on supplier pricing modeling and fuel economy analysis	03/31/2018	Complete
Summary of stakeholder interaction and MA3T-Global development	06/30/2018	On schedule
Project briefing to HQ on charging infrastructure cost-effectiveness analysis and PEV market dynamics modeling	09/30/2018	On schedule

Note: based on adjusted lower funding level

Quantify assumption-impact linkages with systems dynamics models

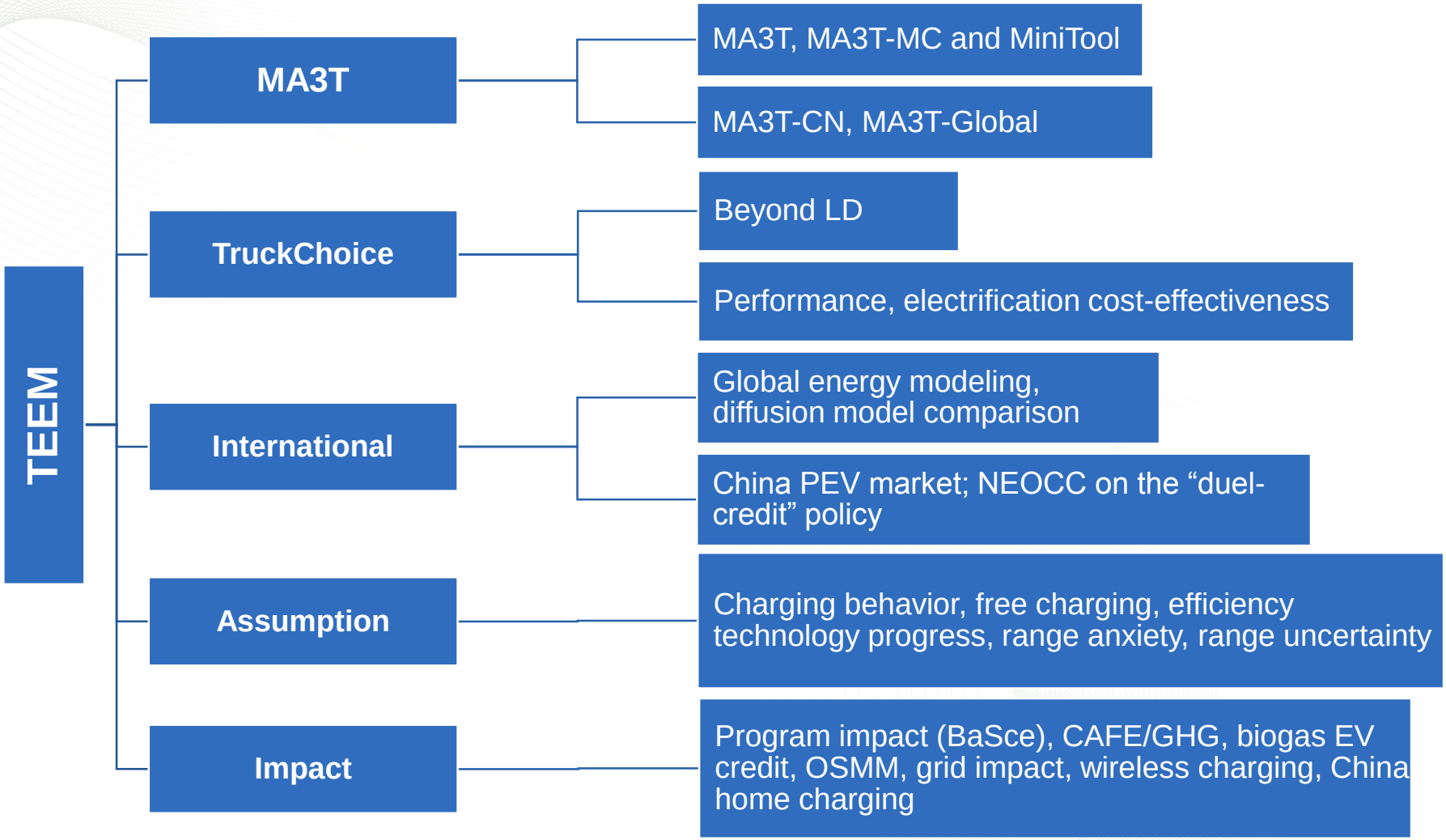


TEEM = Transportation Energy Evolution Modeling

Consumer surveys, stakeholder engagement and existing models

- Consumer surveys
  - Advanced PEV Travel and Charging Behavior survey
  - Beijing Household Travel Survey
  - National Household Travel Survey, 2009 and 2017
  - Seattle GPS travel data
  - Northern California Multi-tasking Travel Survey
  - Mobility services cost-benefit calculator (potentially used for survey)
  - WholeTraveler survey
  - NYC taxi GPS data
- Industry stakeholders
  - Beyond LD Electrification of Goods and People Movement Workshop
  - “Insurance” value of vehicle features
  - Consumer risk aversion
  - China new energy vehicles
  - Automation and electrification
- Linking existing models and capabilities
  - Autonomie, POLARIS, GREET, VISION, SERA, OSMM, HOP, HySEB

Organization of TEEM research activities

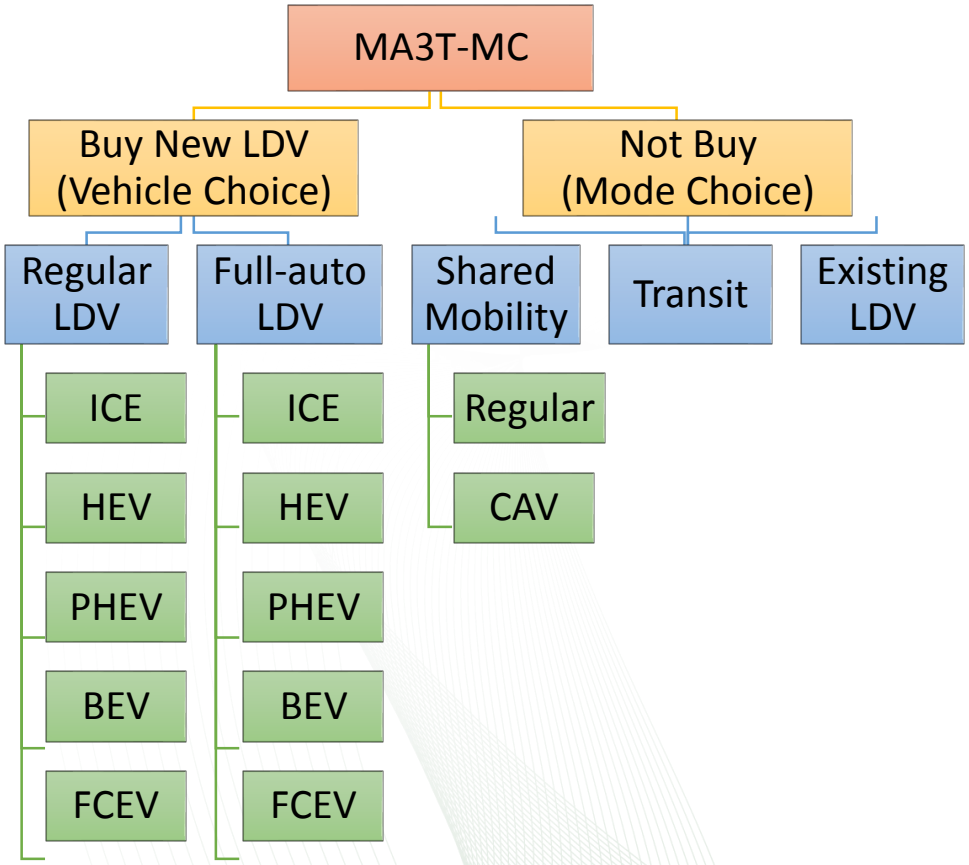


MA3T: more capabilities, more case studies

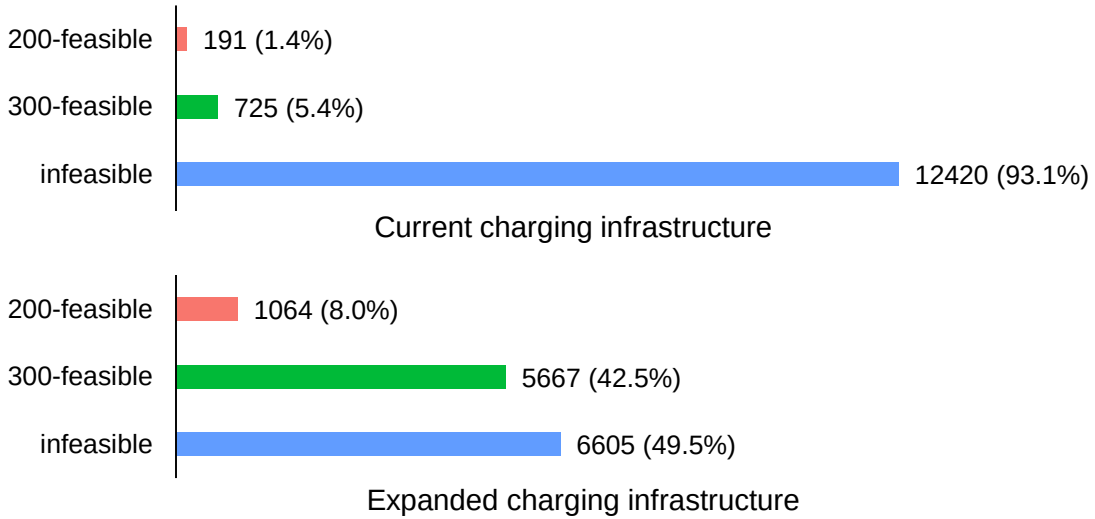
Model Upgrades	Case Study/Accomplishment
Fast charging availability-opportunity linkage	SMART Mobility AFI task #1
Renewable fuel credit	Biogas PEV credit study. Published 1 technical report. Working journal paper
implicit cross-subsidy to represent policy compliance	China PEV market study, one journal paper accepted.
Efficiency cost curve	CAFE/GHG compliance analysis. One journal article published.
New vehicle data	DOE BaSce study
Disaggregate vehicle stock projection	Linked to POLARIS
Safety value and time value of vehicle automation	Market penetration of automated vehicles
Efficiency improvement and range extension from vehicle automation	Synergy between automation and electrification

MA3T-MC: simulating market dynamics of electrification, automation and sharing

- A systematic framework supported by testing and simulation data
- To support SMART Mobility tasks
- Flexible to accommodate user assumptions
  - What if automated vehicles are required to be electric vehicles?
  - What if automated vehicles are not 100% reliable?
  - What if “drivers” of automated vehicles can’t fully recover the travel time cost?



Analyzing BEV Feasibility from NYC Taxi Travel Patterns



- Current 280 public charging stations in NYC are far from sufficient to support a large BEV taxi fleet.
- Adding 372 new charging stations can make BEV-200 and -300 feasible for half of the taxi fleet.

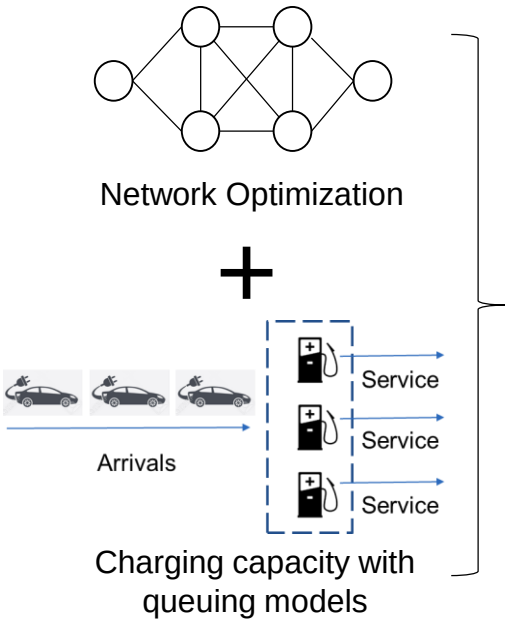
Taxis with certain travel patterns are suitable for switching to BEV-200 or BEV-300:

- fewer daily shifts
- fewer drivers assigned to the taxi
- shorter daily driving distance
- fewer daily dwells but longer dwelling time
- higher likelihood to dwell at the borough of Manhattan

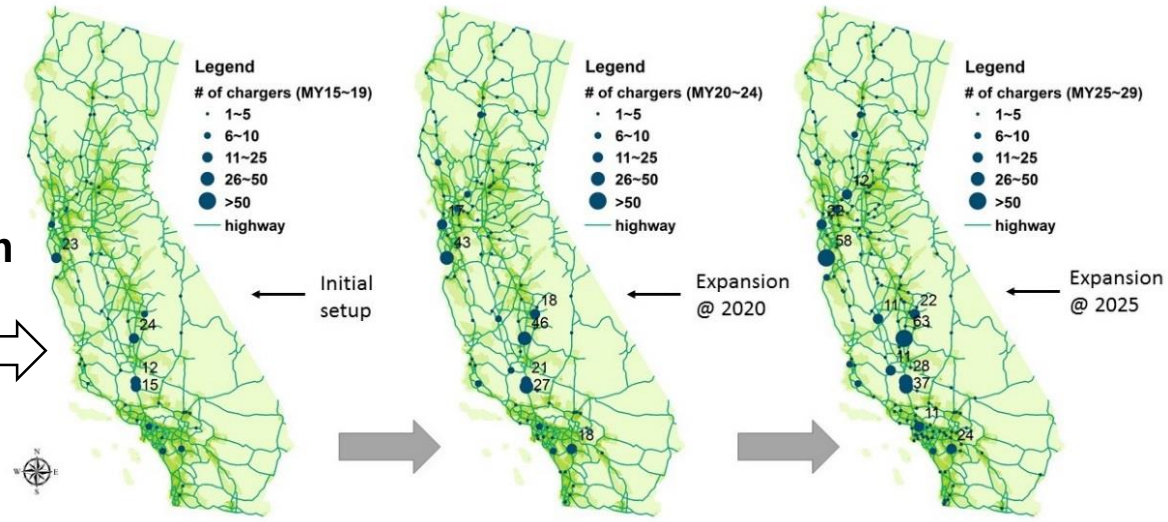
Regional Electric Vehicle Infrastructure Strategic Evolution (REVISE) Model

REVISE Model Achievements:

- The REVISE model aims to determine corridor DCFC infrastructure requirement to meet the growing inter-city travel demand of BEV users
- The model could determine where and when charging stations are opened, and how many chargers are required based on certain level of service
- The model integrates both network optimization and queuing theories and is solved using genetic algorithm
- The model is applied to a regional case study in California with planning horizon from 2015 to 2029.



Genetic Algorithm

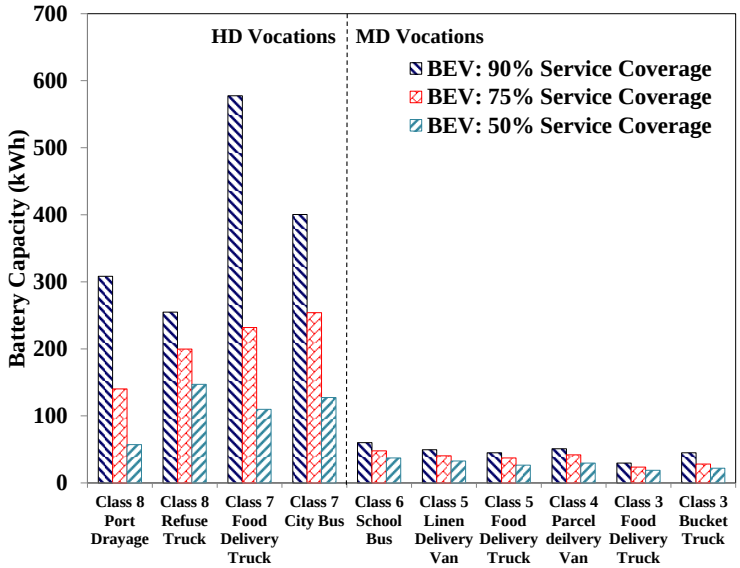


To meet growing BEV demand, charging infrastructure expands in both network coverage (more stations) and service capacity (larger station)

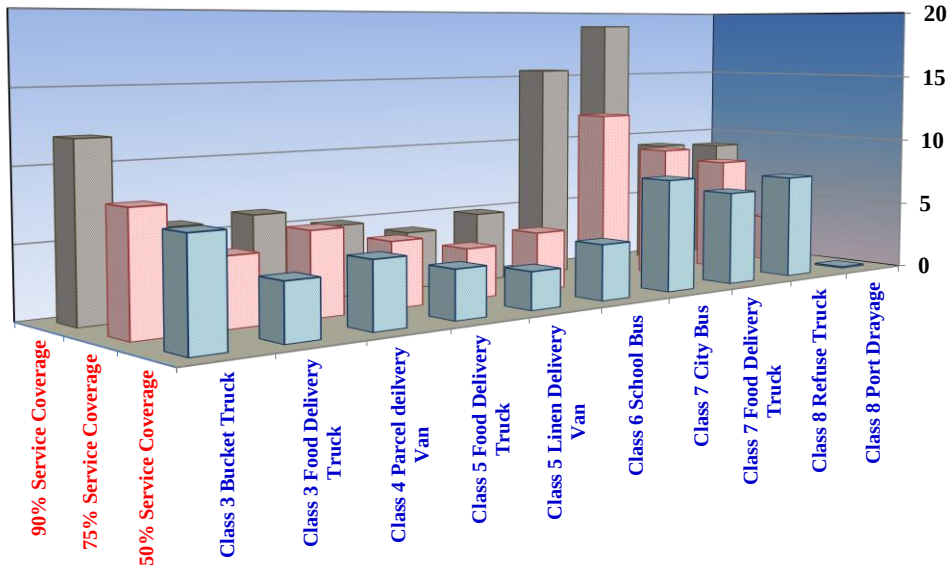
MA3T-TruckChoice: commercial vehicle (MD and HD) electrification analysis with duty-cycle data

- Provide insights into BEV feasibility and cost-effectiveness across types and duties of MD/HD vehicles, and identifies high-potential MD/HD electrification technologies and market opportunities
- The FleetDNA-based Commercial Vehicle Electrification Evaluation Tool (CVEET)
- Class 3-6 MD electrification is more feasible with practical battery size, better service coverage and less payback time, and Class 7-8 HD electrification fits short-distance service

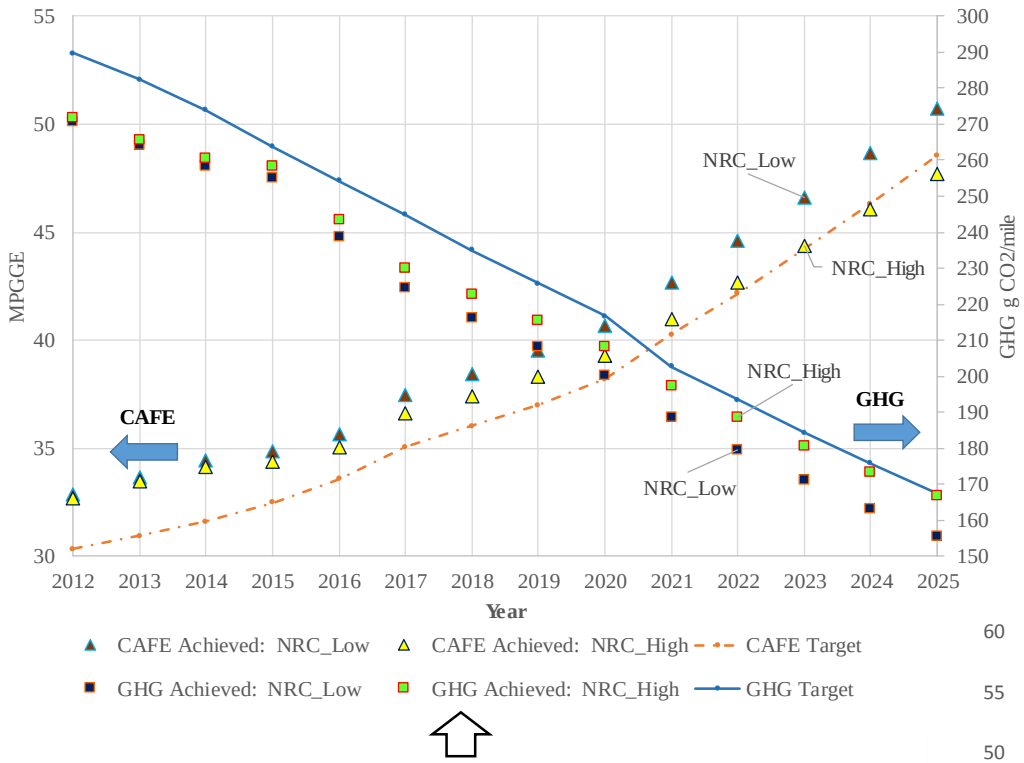
Impact of BEV Service Coverage on Battery Capacity

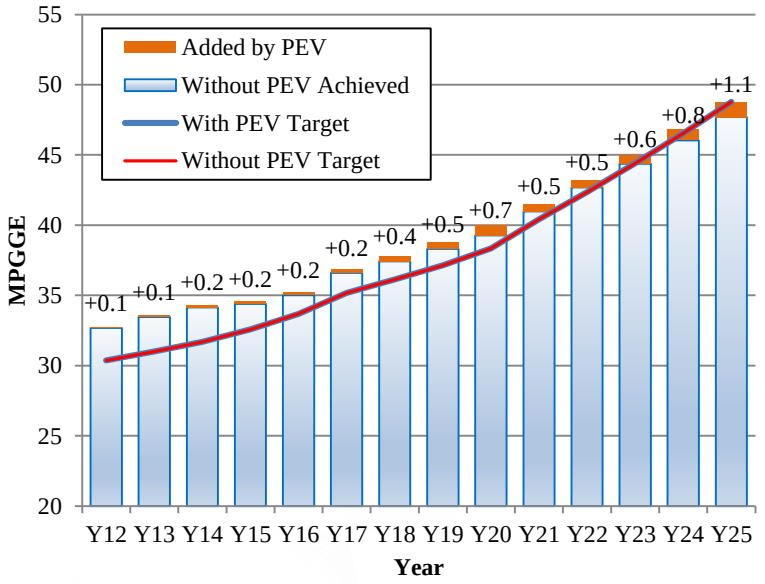


Electrification Payback Period



Consumer-choice-based Compliance Analysis of CAFE and GHG Standards

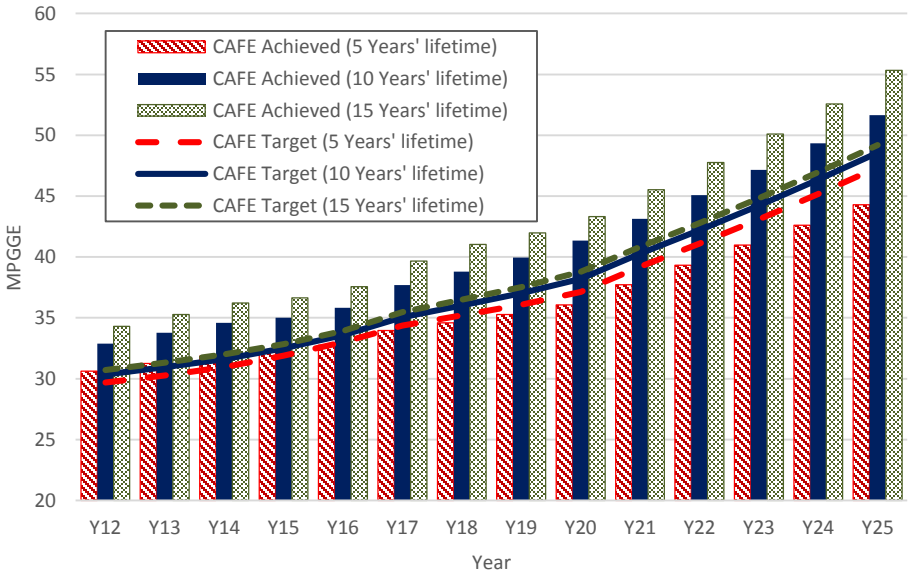




PEVs significantly enhance compliance capability

Industry can comply with both CAFE and GHG standards even with high cost project and without PEVs in both 12-16 and 17-25 periods

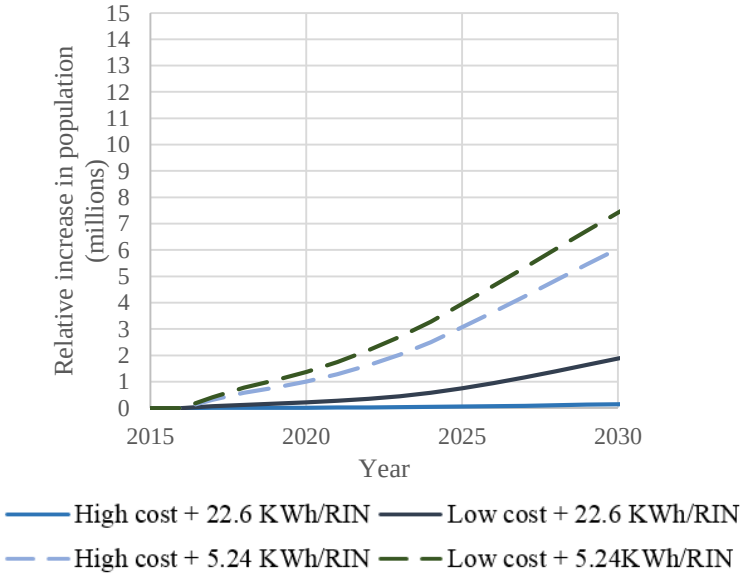
Uncertainty in valuation of fuel economy or perceived lifetime may significantly affect ability to comply with the standards. In the graph, 5 years' lifetime indicates undervaluation scenario which indicates that risks are present to comply with the CAFE standards



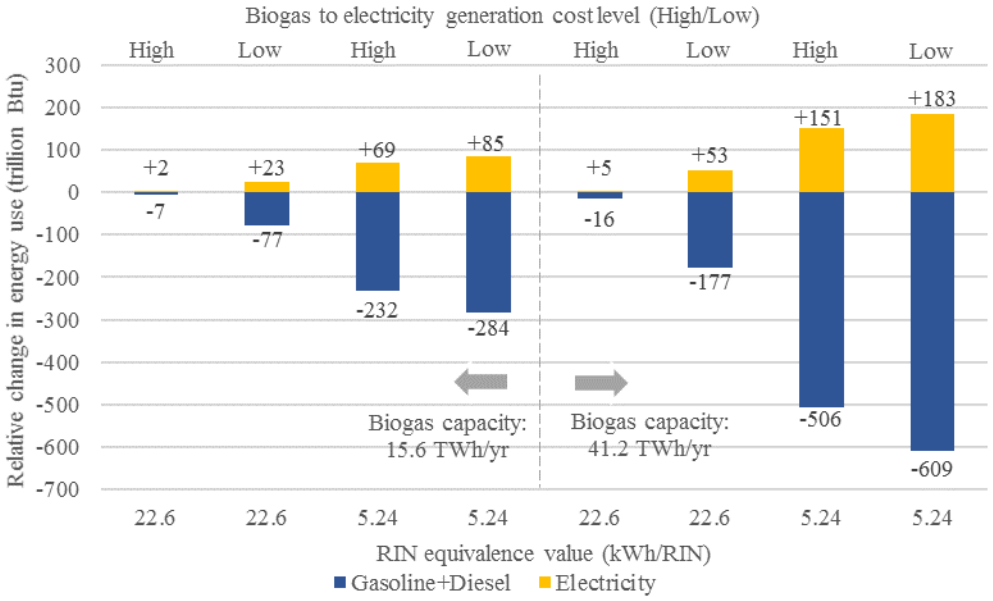
Impact Analysis of Biogas-to-Electricity Annual Rebate Program with MA3T

(Co-funded by EERE Office of Strategic Programs)

- Credits generated with biogas electricity used in transportation could stimulate PEV sales
- Evaluate a potential biogas electricity credit allocation method (within RFS) using the MA3T model
- Assess the impact on PEV deployment and energy use



- Relative changes in BEV population compared to the “No Program” scenario
- Changes in population are significant with the biogas electricity program



- change in energy use in 2030 compared to the “No Program”
- The program could reduce the use of conventional fuel, but increase the electricity usage

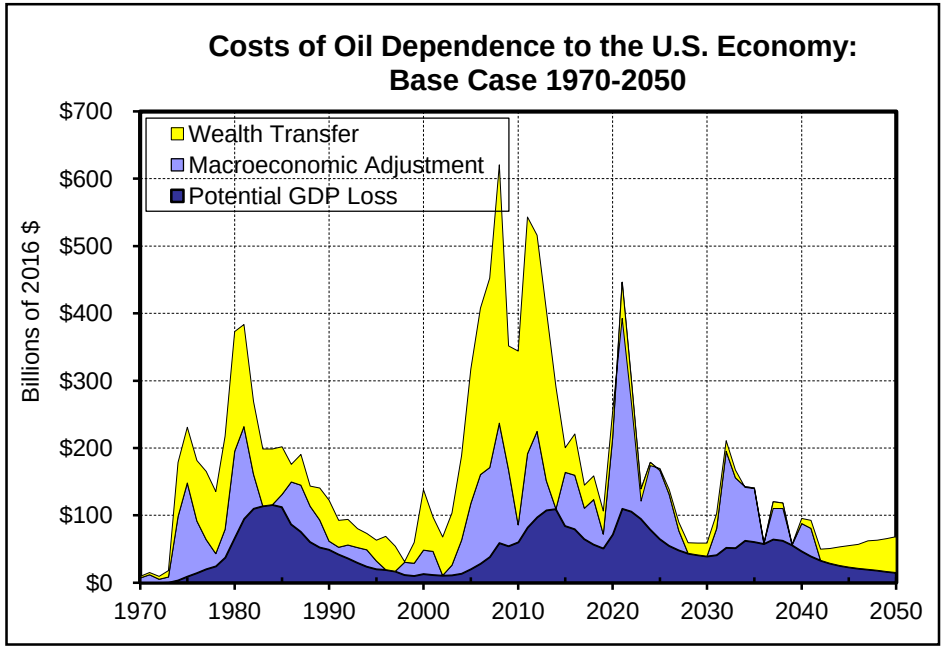
Oil Security Metrics Model (OSMM) with EIA AEO 2018

How will the EERE R&D projects reduce oil dependence in the U.S. economy?

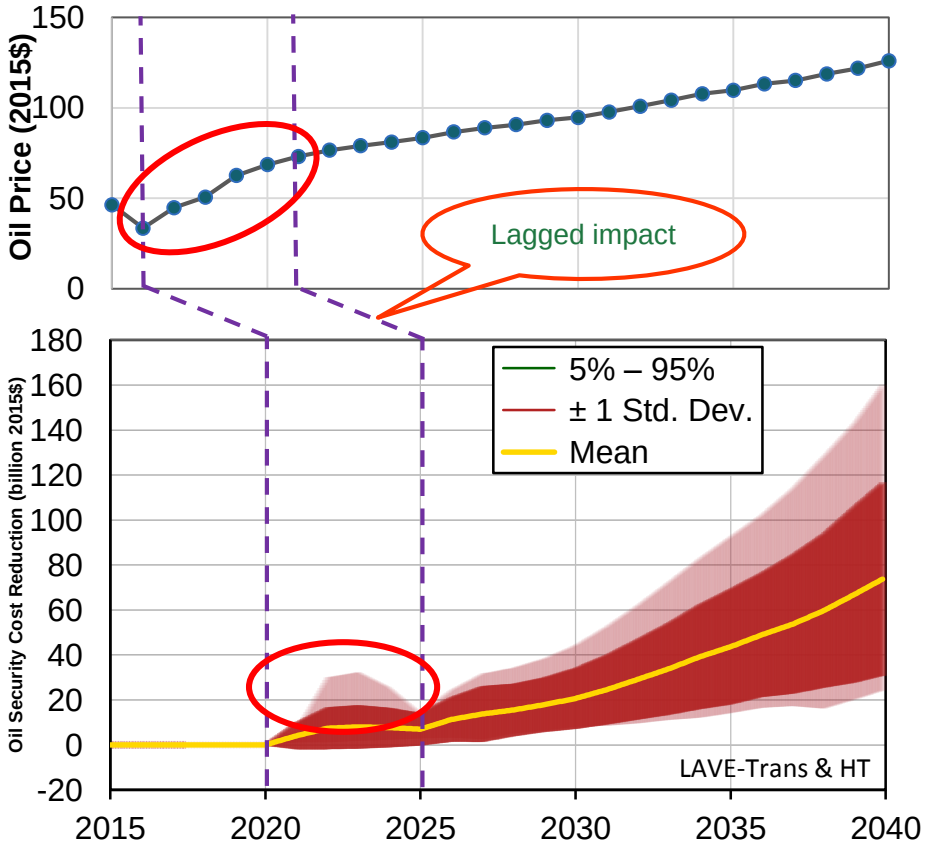
Total oil dependence = Wealth Transfer + Potential GDP impact + Macro disruption (Oil shocks)

Accomplishments:

- Updated and released the version of OSMM-2018 with Annual Energy Outlooks (AEO) 2018.
- OSMM structure was revised and the projected time frame was extended from 2016-2040 to 2016-2050.
- Sensitivity analysis: a fast oil price growth might bring a larger uncertainty on the oil dependence cost. (illustrated with OSMM 2016 version)



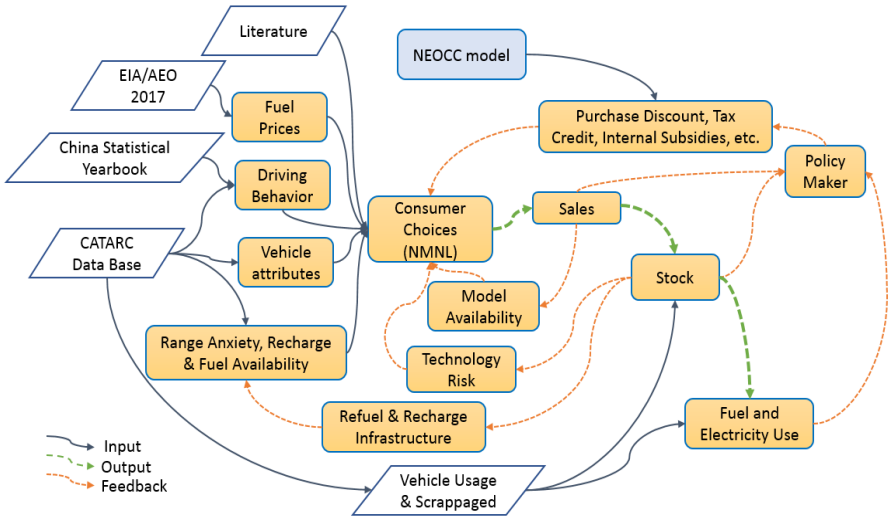
Oil dependence analysis with OSMM 2017

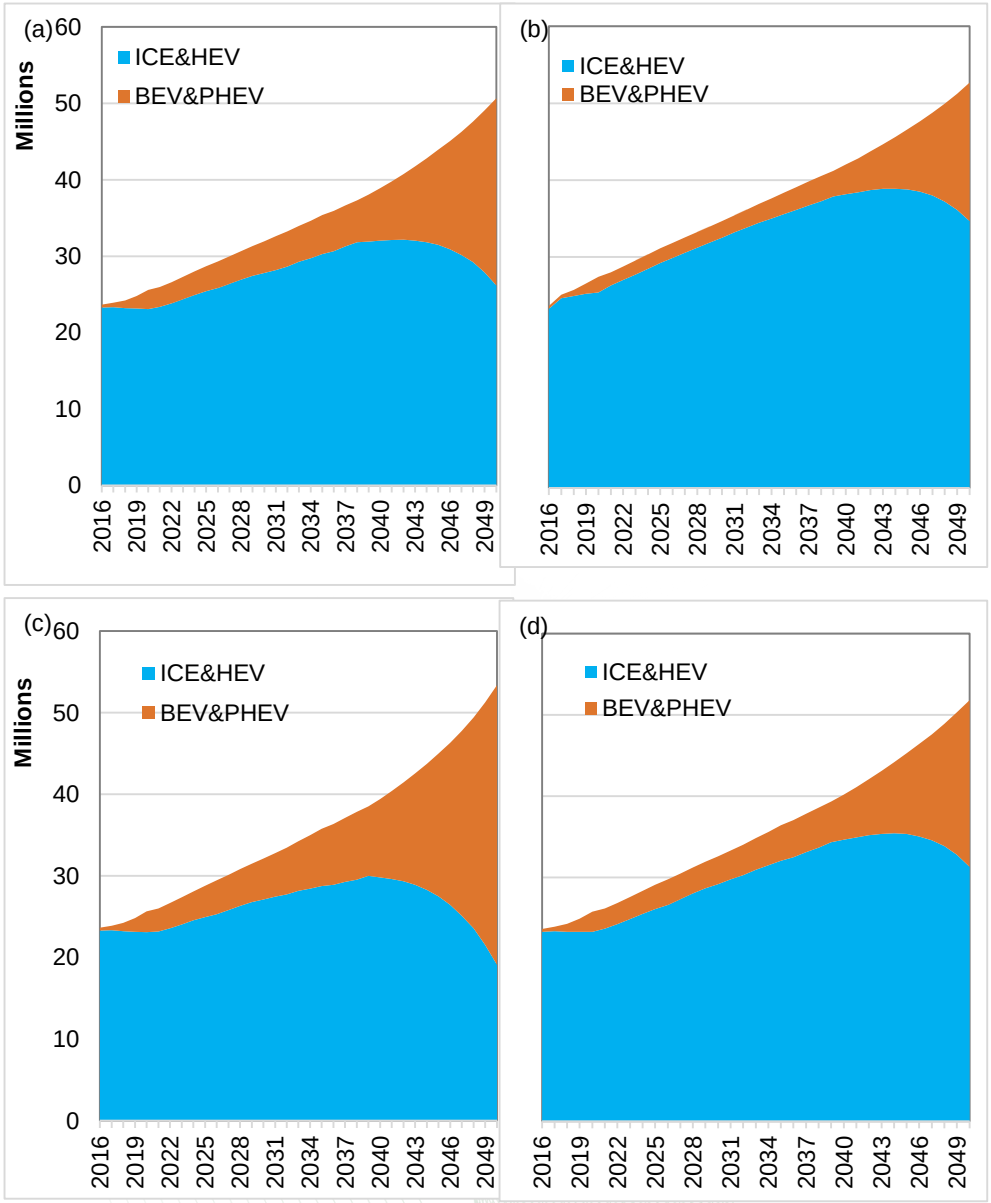


The uncertainty of oil reduction projection in OSMM 2016 with MA3T&HT

MA3T-China: analysis tool on China vehicle electrification trend

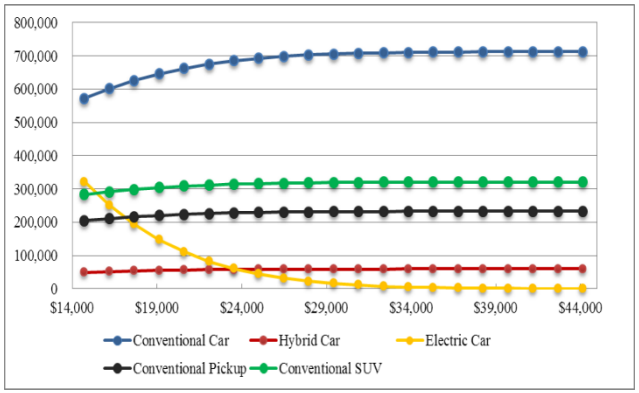
- Scenario definitions: (a) base case: impacts by dual-credit regulation in 2017-2020; (b) scenario with impacts by low oil prices in 2017-2050; (c) scenario with impacts by low battery costs in 2017-2050; (f) scenario with impacts by high efficient CV in 2017-2050.
- Funded by ***Aramco Services Company*** and adapted from VTO-funded US-focused MA3T, the MA3T-China model reflects Chinese travel patterns, vehicle costs, fuel prices, land use, and policies.
- Calibrated to historical sales and price data in China



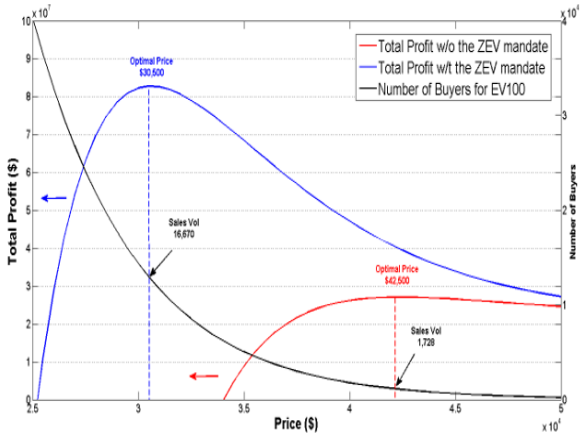


Electric Vehicles Pricing and Market Adoption: California

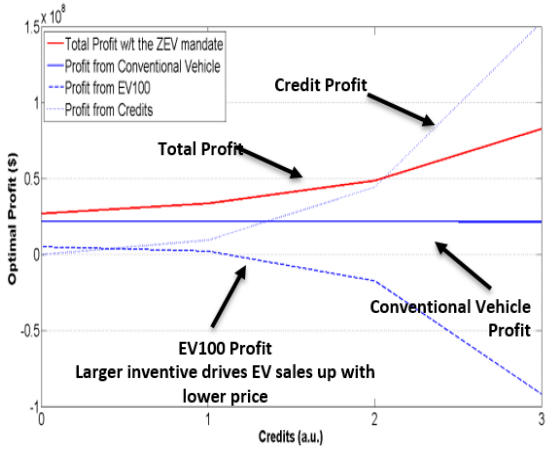
- A theoretical study of technology pricing problems under tradable credit subsidy
- Investigation of California automotive market and comprehensively assess the role of the Zero Emission Vehicle (ZEV) mandate during the transition to electric vehicles with the model
  1. Credit revenue support the offering of EVs
  2. The ZEV mandate substantially reduces EV price
  3. Higher credit profitability can help further diffusion of EVs but there is a cap for the impact



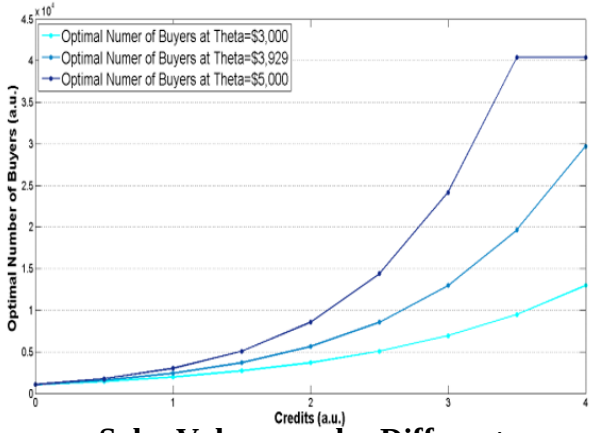
Demand for different types of vehicles at different prices of EV100 model.



Sales/Profit Forecast for EV100 Model with Optimal Price



Profit Disaggregation under Different ZEV Credits



Sales Volume under Different ZEV Credits

FY17-18 accomplishment summary

- Made significant progress on models/tool development
  - MA3T, MA3T-MC, MA3T-CN, MA3T-Global
  - MA3T-TruckChoice with CVEET on commercial vehicle electrification
  - NEOCC (for the China CAFC/NEV credit policy)
- Applied market dynamics models on various issues
  - DOE program impact analysis (BaSce study)
  - Biogas electricity credit impact on EV market
  - CAFE/GHG compliance analysis
- A productive year on publication
  - 8 peer-reviewed articles or reports; 8 submitted for publication review; 9 working drafts

Responses to Previous Year Reviewers' Comments

- "validation and verification of the model was not discussed during the presentation and it was unclear to the reviewer whether this step is occurring or not"
  - Response: MA3T and MA3T-China have been calibrated to historical sales and price data. Calibration of MA3T-MC and MA3T-Global are being conducted. Validity of these models are achieved though peer reviews on the usefulness, transparency, consistency and logicality (Senge and Forrester, 1980)
- Alternative specific constants for both choice and choice category; how ASCs are specified for future
  - Response: Because adding an ASC for a choice category can be equivalent to adding a constant (may not be the same value) to all choices in that category. With this spirit, we chose to adjust ASCs for each choice to achieve the same modeling outcome. ASCs for the future are determined based on certain vehicle class-level assumptions. For example, all car choices' ASCs are assumed to converge to the same value in 2050, while all SUV choices' ASCs converges to the same value, but different from that for cars. Documentation are being prepared.

Collaboration and Coordination

Topic	Collaborator Institution
MA3T	VTO, SRA, ANL, NREL, UTK, KAPSARC, SRA
MA3T-Global	IIASA, UTK
MA3T-CN	Aramco, CATARC
Fleet vehicle EV	Energetics, NREL, Iowa S. U.
Charging behavior	Iowa S. U., INL, LBL
Consumer attitude linkage	George Tech
Consumer mobility choice	UT Austin
Biogas EV credit	VTO, BETO, EPSA
DOE program impact	VTO, FCTO, ANL, SNL, NREL, Energetics, UTK
PEV usage behavior	UC Davis
International PEV market	UC Davis, U. of Maryland, IIASA, CATARC
Charging infrastructure	Clemson U., Iowa S. U.
PEV incentives	SRA, VTO
Energy security	UTK

MA3T being expanded to MA3T-MC to simulate market dynamics among electrification, automation and shared mobility

U.S. DEPARTMENT OF ENERGY
SMARTMOBILITY
Systems and Modeling for Accelerated Research in Transportation

- work in progress, funded by VTO EEMS/SMART Mobility

CAV energy impact

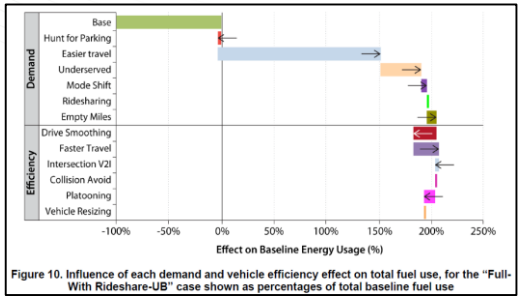
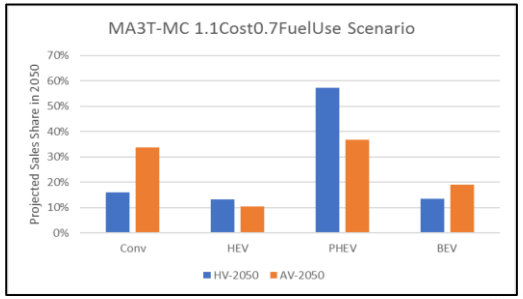
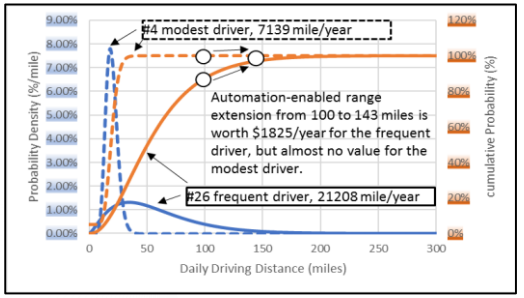


Figure 10. Influence of each demand and vehicle efficiency effect on total fuel use, for the "Full-With Rideshare-UB" case shown as percentages of total baseline fuel use

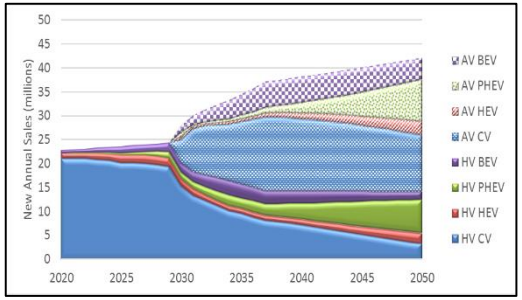
AV and PEV



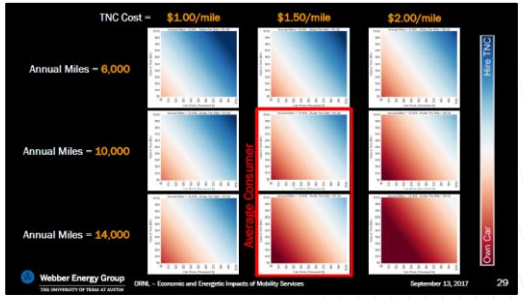
Consumer heterogeneity



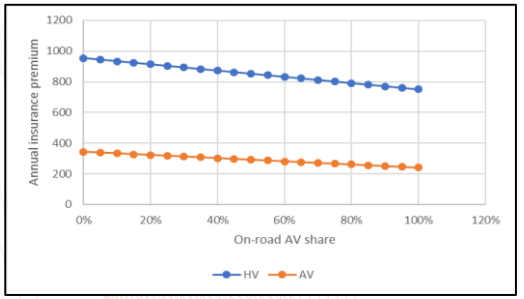
Market penetration



Shared mobility or own



Network effect



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Remaining Challenges/Barriers

- Projecting PEV costs that may be affected, via economy of scale and technology spillover, by the emerging international market, especially China.
- How connectivity and automation may affect consumer adoption of PEVs.

Proposed Future Research

- MA3T-Global development (Q3 milestone)
- charging infrastructure cost-effectiveness analysis and PEV market dynamics modeling (Q4 milestone)
- FY19
  - Meta analysis on consumer valuation of shared mobility
  - Validate MA3T-MC

Any proposed future work is subject to change based on funding levels

TEEM FY16-17 Summary

- Transportation energy transition is of high relevance to DOE
- TEEM focus on market dynamics and transition of highway vehicle fuel technologies
- MA3T has attracted multiple sponsorships beyond VTO Analysis
- FY17-18 so far with good progress and productivity
  - Important model upgrades
  - A few important studies
  - Multiple publications
  - Successful collaboration
- FY18-19 to continue model improvements and case studies
  - Core models: MA3T, MA3T-China, MA3T-Global and MA3T-MC
  - Others: OSMM, NEOCC, HOP, CVEET, REVISE, etc.

ACKOWLEDGEMENTS

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Contact:

Zhenhong Lin
Principle Investigator
National Transportation Research Center
Oak Ridge National Laboratory
(865) 946-1308
linz@ornl.gov

Technical Backup Slides

Selected acronyms explained

CAV	Connected and automated vehicles
CV	Commercial vehicle
MA3T	Market Acceptance of Advanced Automotive Technologies
MA3T-MC	MA3T-MobilityChoice
MaaS	Mobility as a Service
NEOCC	New Energy & Oil Consumption Credit
SM	SMART Mobility
TEEM	Transportation Energy Evolution Modeling
HOP	Hydrogen Optimal Pressure
HySEB	Hydrogen Station Economics and Business
OSMM	Oil Security Metrics Model